

Gas Turbine Industrial Fellowship Program 2006

Development of a Simple Design Rule for Tandem-Blade Compressor Rotors

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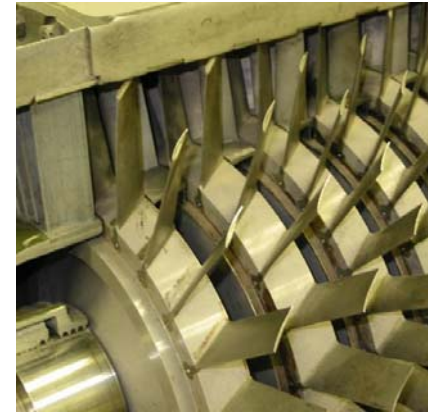
Mentor: Dr. Steven R. Wellborn, Compressor Aero



Gas Turbine Need: Reduce Number of Compressor Stages

- Motivation
 - Fewer stages means smaller compressors
 - Increased Power-to-Weight ratio
- Tandem-Blade rotors can possibly achieve this goal
- Project Objectives:
 - Develop simple design rule for pitchline design of tandem-blades
 - Compare model predictions to CFD

Traditional Single-Blade Compressor



Tandem-Blade Compressor



Background: What is a Tandem Blade?

- Two airfoils on a common wheel
- Physics:
 - New boundary layer forms on A.B.
 - Can get more turning, $\alpha_1 - \alpha_2$, (i.e. more work) than a single blade
 - Less risk of flow separation: lower loss than single blade

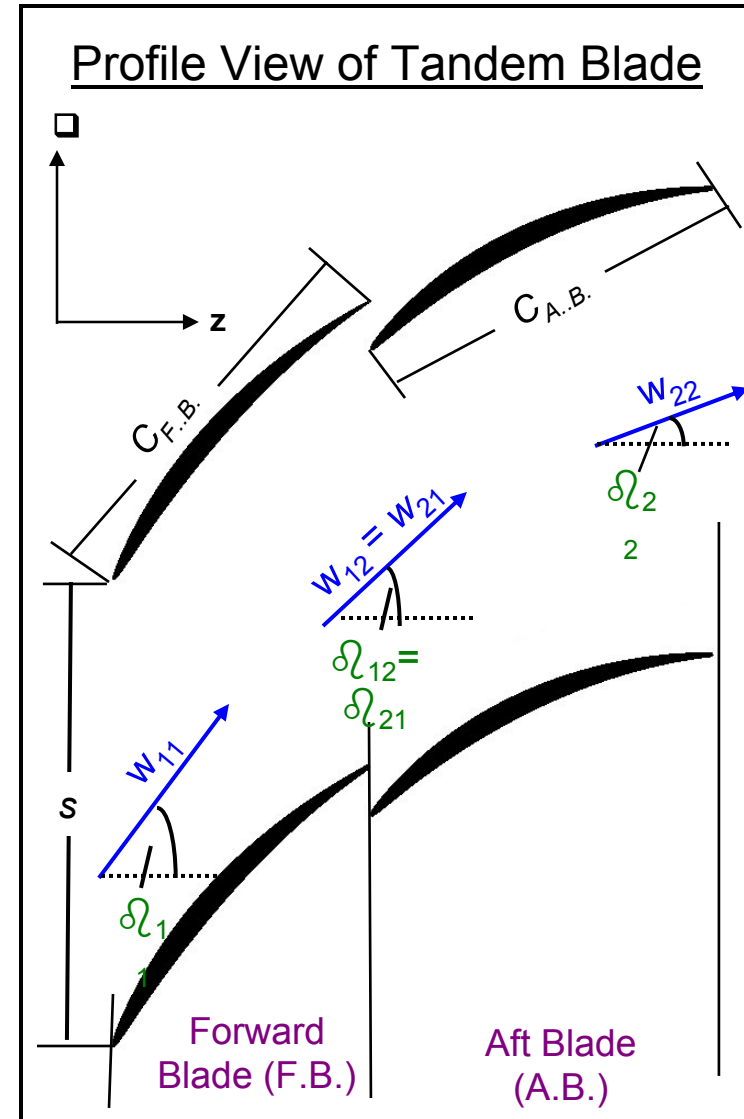
Geometric Parameters:

$$C_{eff} = C_{F.B.} + C_{A.B.}$$

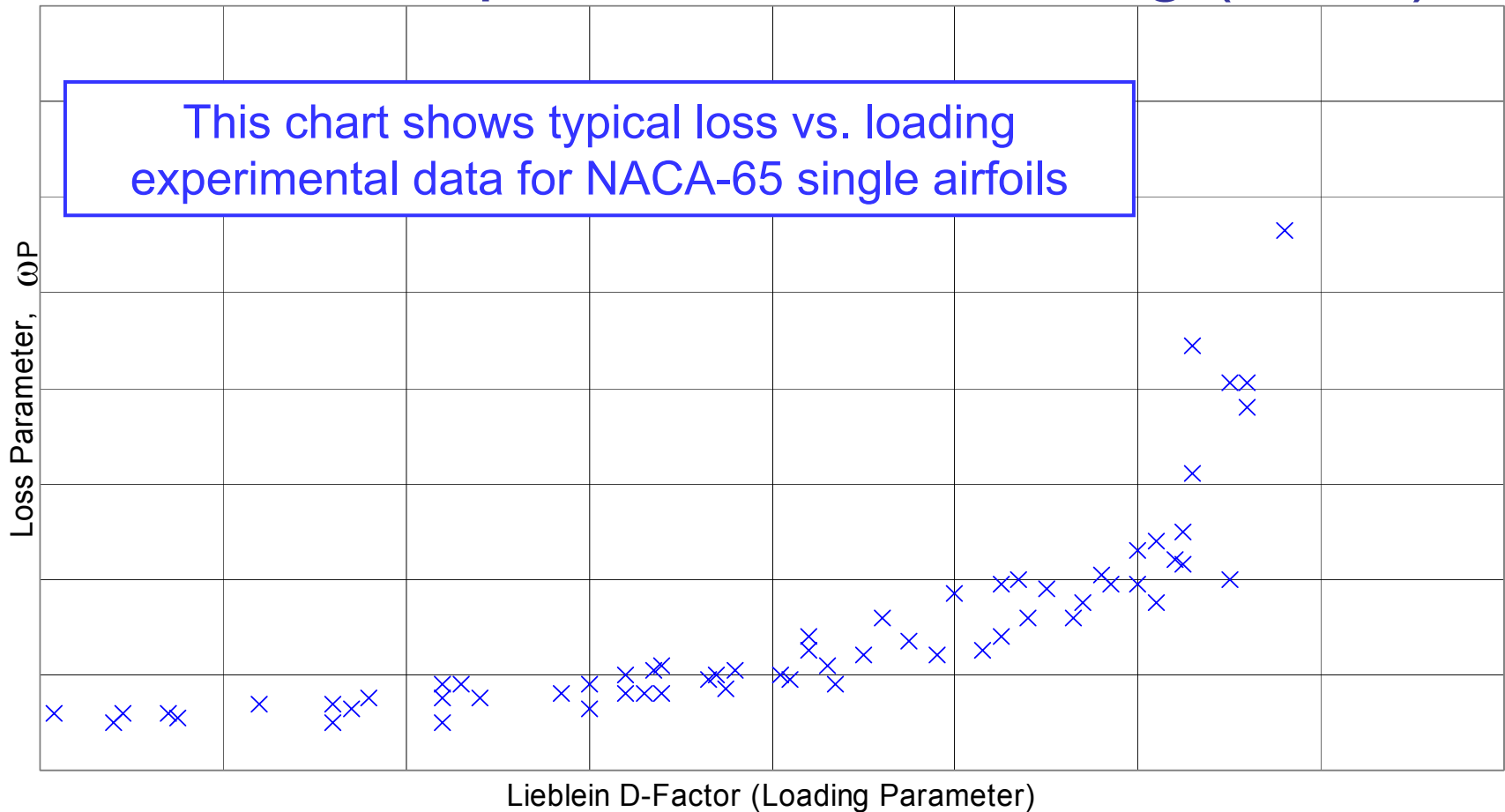
– Effective Chord:
$$\sigma_{eff} = \frac{C_{F.B.} + C_{A.B.}}{s}$$

– Effective Solidity:

- Above definitions assume no axial overlap of the blades



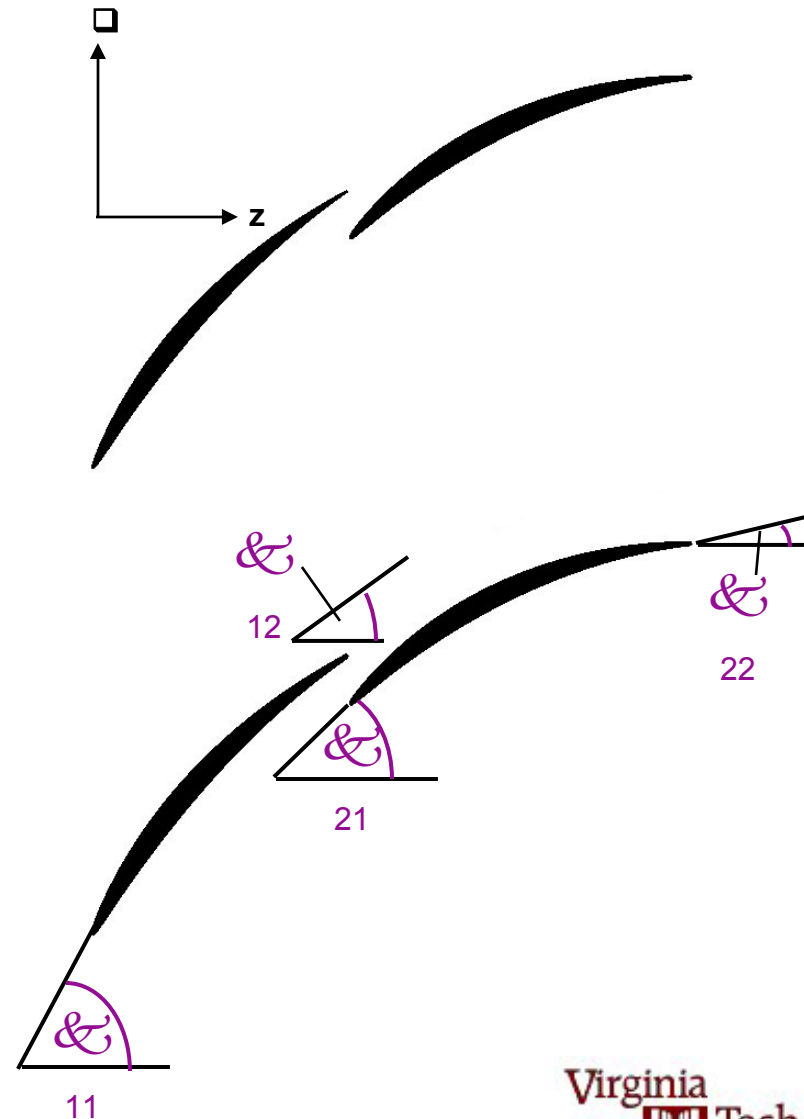
Desired Output: Loss vs. Loading (Work)



By specifying the desired Forward and Aft blade D-Factors, we can estimate the total loss and loading of the tandem configuration

Desired Output: Blade Metal Angles

- Need metal angles (α_{11} , α_{12} , α_{21} , α_{22}) for minimum-loss flow condition
- We can use published data to determine metal angles from the min. loss flow angles

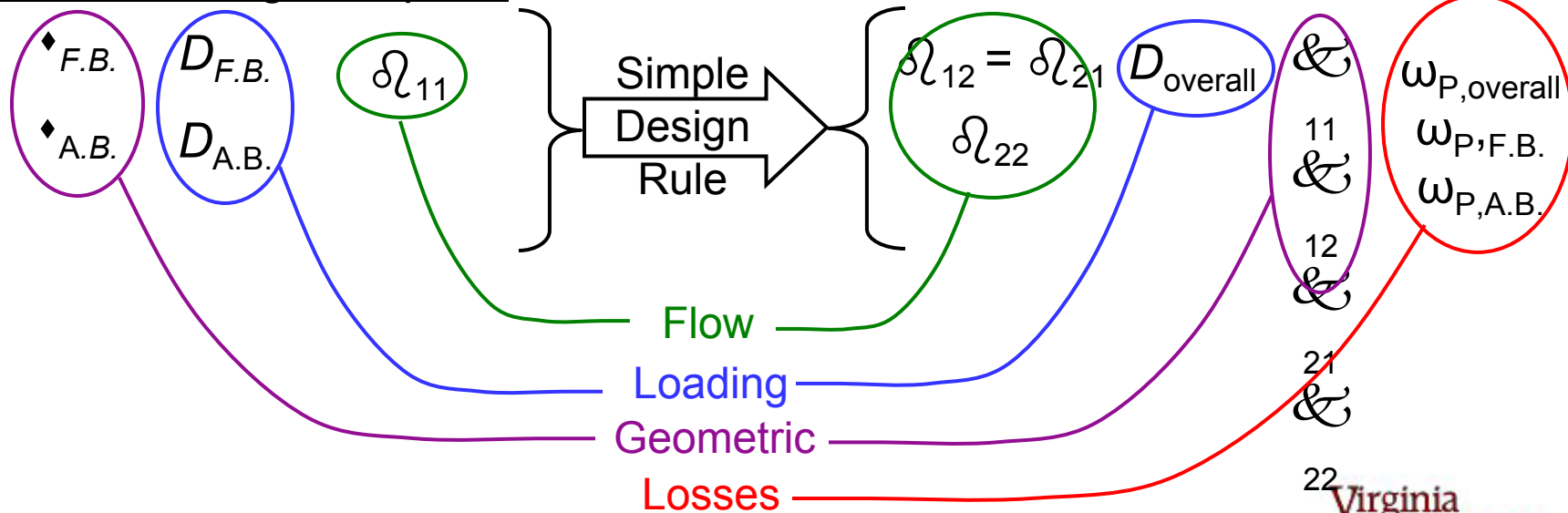


Simple Design Rule Usage: Inputs / Outputs

- Assumptions:
 - No interaction between the Forward and Aft Blades
 - Blades are at minimum loss incidence (α^*)
 - Incompressible flow, constant axial-velocity
- Sum individual blade loadings & losses
- Metal angles (α_{11} , α_{12} , α_{21} , α_{22}) come from NACA-65 data

Specify the following as inputs:

And get the following outputs:



Results: Simple Design Rule vs. CFD

NACA-65 tandem airfoils with an Inlet Mach No. of 0.6

Loss Parameter, ΔP

Simple Design Rule

CFD

Simple Design Rule captures trend well compared to a full-fledged CFD analysis

D-Factor



Summary of Simple Design Rule

Advantages

- Uses simple pitchline parameters as inputs / outputs
- Computational time ~10 min. vs. 1+ hour for one CFD case
- Captures loss vs. loading trends reasonably well
- Serves as a good starting point for design of tandem rotors

Drawbacks

- Relies on experimental data to estimate loss, which is not readily available for all airfoil families
- Assumes incompressible flow, which is not the case for most compressor stages
- Does not account for interaction effects between Forward and Aft blades

As with most engineering problems, there is a clear tradeoff between time and effort required versus accuracy of result

Acknowledgements

- Steven R. Wellborn, Compressor Aero
- Severin Kempf, Compressor Aero
- Robert Delaney, R-R UTSR Contact
- The hard workers at NACA (now NASA) whose experimental work made this project possible

